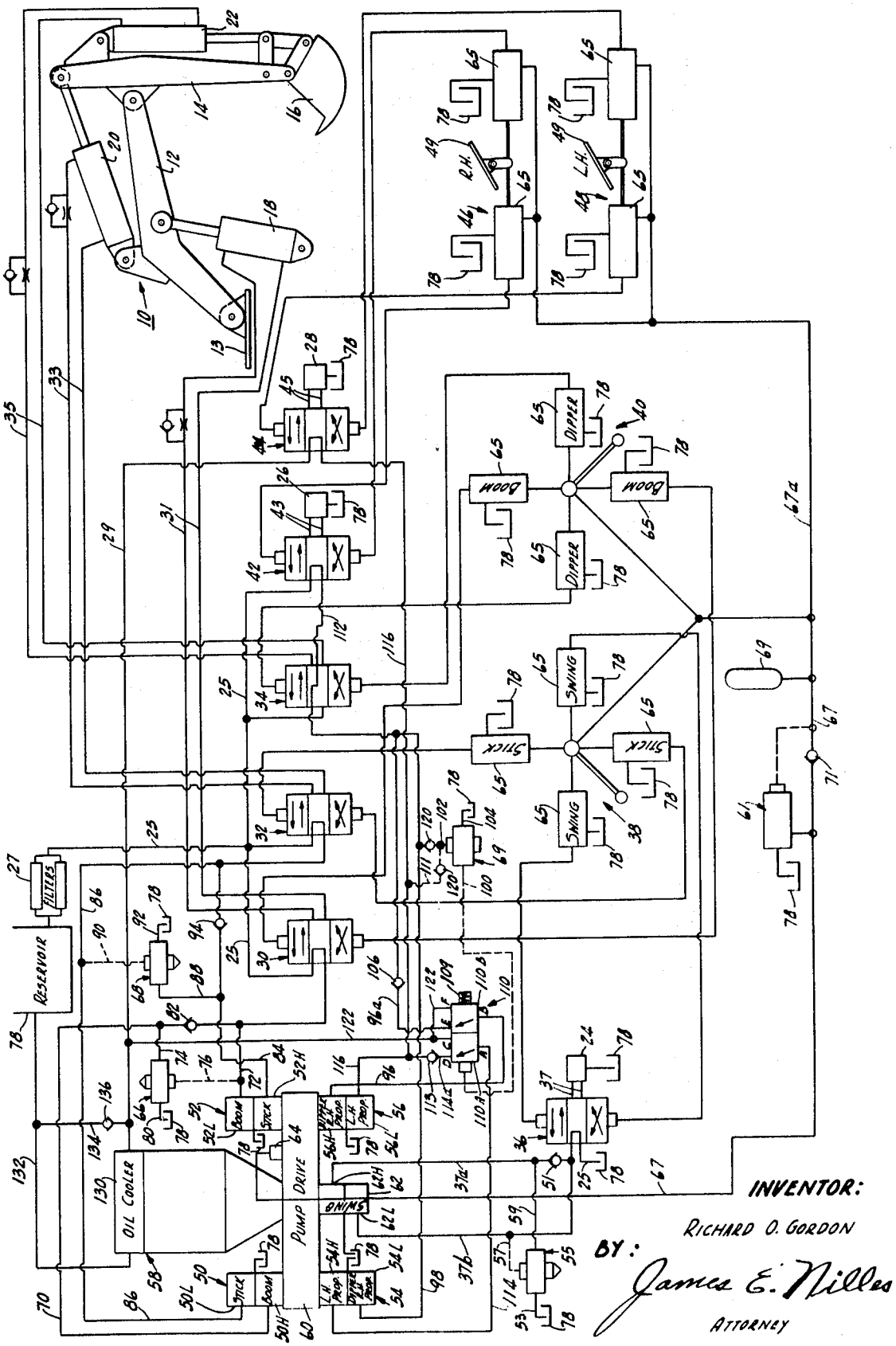
Sept. 20, 1971 R. O. GORDON 3,606,049

HORSEPOWER LIMITING HYDRAULIC CONTROL CIRCUIT

Filed Nov. 12, 1969



United States Patent Office 3,606,049 Patented Sept. 20, 1971

3,606,049

HORSEPOWER LIMITING HYDRAULIC CONTROL CIRCUIT

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Filed Nov. 12, 1969, Ser. No. 875,797
Int. Cl. E02f 3/30
U.S. Cl. 214—138 8 Claims

ABSTRACT OF THE DISCLOSURE

A horsepower limiting hydraulic power transmission system for hydraulically operated lifting and digging equipment including a number of hydraulic cylinders and motors for controlling the various functions of the equipment. The system includes a number of double, fixed volume pump assemblies operatively connected to the main engine, each pump assembly including a high volume-low pressure pump and a low volume-high pressure pump, one high volume pump from each assembly being cross connected to one of the low volume pumps of another pump assembly to provide hydraulic fluid for one of the cylinders or motors; a pilot operated valve connected across each pair of cross connected pumps, each of the valves is responsive to the pressure of the low volume-high pressure pump to bypass the fluid from the high volume-low pressure pump to the reservoir. A double acting hydraulically actuated valve is included and is responsive to the pressure of either of two low volume pumps to simultaneously by-pass both corresponding high volume pumps and thereby simultaneously shift two operating functions from high horsepower to low horsepower operation.

BACKGROUND OF THE INVENTION

Hydraulically operated equipment of the type with which the present invention finds particular utility, generally includes a moveable bucket or dipper pivotally mounted on a dipper stick which in turn is pivotally mounted on a boom. The boom is pivotally mounted on a frame, and the frame is mounted for horizontal swinging movement on a truck or carriage. The truck is propelled by hydraulically driven tracks or wheels. The dipper, dipper stick, boom, swing frame and tracks are conventionally actuated by hydraulic cylinders or motors supplied with pressurized fluid from a hydraulic pump driven by the main engine. The capacity or rating of the engine must also be sufficient to meet the maximum contemplated horsepower requirement for operating the hydraulic cylinders and motors. Maximum horsepower is required whenever the movement of the dipper, dipper stick or boom is retarded by an extra heavy load or an immovable object. If the load on the engine is not dropped almost instantly, the engine will normally stall. In order to prevent unnecessary stalling of the engine, variable volume piston pumps have been used to limit horsepower required from the engine by reducing the volume of fluid and increasing the pressure of the hydraulic fluid; however, these pumps are expensive and require frequent maintenance.

SUMMARY OF THE INVENTION

The hydraulic horsepower limiting system of the present invention overcomes the above problem of stalling and unnecessary waste of horsepower by providing an immediate or instantaneous shift to low horsepower operation whenever the pressure of the hydraulic fluid in any portion of the system exceeds a predetermined amount. This is accomplished by using a plurality of low cost double fixed volume pump assemblies to provide the hydraulic

fluid required to operate the cylinders for the boom, dipper stick and dipper and the motors for the swing frame and the propel tracks. Each of the double fixed volume pump assemblies includes a high volume-low pressure and a low volume-high pressure pump. The high volume pump in each assembly is cross connected with the low volume pump of another assembly to provide the required hydraulic fluid to operate one of the hydraulic cylinders or motors up to the operating pressure of the high volume pump. Horsepower is saved by connecting a pilot operated valve to respond to the pressure of the low volume-high pressure pumps to by-pass the high volume pumps whenever this pressure exceeds the operating pressure of the high volume pump. The low volume-high pressure pump will continue to provide fluid at a higher pressure, however, the low volume pump requires less horsepower to operate.

The propel pumps for the tracks are also cross connected to prevent high speed operation of one propel motor and low speed operation of the other propel motor at the same time. This is achieved by providing a hydraulically actuated selector valve in the hydraulic lines for the propel pumps to simultaneously shift the propel pumps from low pressure to high pressure operation.

These and other objects will become more apparent from the following description when read in connection with the accompanying drawing in which a schematic diagram of the invention is shown.

DESCRIPTION OF THE INVENTION

The horsepower limiting hydraulic transmission system of this invention is adaptable to almost any hydraulically operated lifting or digging equipment and is described in the drawings with reference to the operation of a back hoe or digger **10**. This type of a device generally includes a boom **12** pivotally connected to a frame **13**, a dipper stick **14** pivotally connected to the boom **12** and a dipper **16** pivotally connected to the dipper stick **14**. The raising and lowering movement of the boom **12** is controlled by a double acting hydraulic cylinder **18** connected between the frame and the boom. The movement of the dipper stick **14** is controlled by a double acting hydraulic cylinder **20** connected between the boom **12** and the dipper stick **14**. The movement of the dipper **16** is controlled by a double acting hydraulic cylinder **22** connected between the dipper stick **14** and the dipper **16**. The frame **13** for the boom is generally mounted for horizontal rotation on a carriage (not shown) and is rotated by a hydraulically actuated swing motor **24**. The carriage can be mounted for movement on tracks or wheels which are driven by hydraulically actuated propel motors **26** and **28**.

The hydraulic cylinders **18**, **20** and **22** for the boom, dipper stick and dipper are controlled by means of reversing valves **30**, **32** and **34**, respectively, which are connected to the cylinders by lines or conduits **31**, **33** and **35**. The direction of motion of the swing motor **24** is controlled by means of a reversing valve **36** connected to the motor **24** by lines **37**. The propel motors **26** and **28** are controlled by reversing valves **42** and **44**, respectively, connected to the motors by lines **43** and **45**. Reversing valves **30**, **32**, **34**, **36**, and **42** are connected to a reservoir **78** by a common line **25** through a filter **27**. Reversing valve **44** is connected to the reservoir **78** by a line **29** through an oil cooler **130** as described below.

The reversing valves for the boom, dipper stick, dipper and swing motor are actuated by means of joy stick assemblies **38** and **40**. More particularly, the stick assemblies **38** and **40** each include a number of pressure regulating valves **65**. Means are provided for supplying hydraulic fluid to the valves **65** in the form of a pump **64** driven by means of a main engine **58** through a pump drive **60**. The main engine **58** is rated at 450 horsepower

at 2100 r.p.m. The pump **64** is connected to the valves **65** by a line **67**. An accumulator **69** and a check valve **71** are provided in the line **67** to maintain a constant pressure on the valves **65** and a pilot operated unloading valve **61** is connected across check valve **71** to bypass fluid from the pump **64** to the reservoir **78**. The assembly **38** is shown connected to control the reversing valve **36** for the swing motor **24** and the reversing valve **32** for the dipper stick **14**. The joy stick assembly **40** is connected to control the reversing valve **30** for the boom **12** and the reversing valve **34** for the dipper **16**.

The reversing valves **42** and **44** for the propel motors **26** and **28** are controlled by foot control assemblies **46** and **48**, respectively. Each of these assemblies includes a pair of pressure regulating valves **65** which are controlled by foot pedals **49**. Hydraulic fluid is supplied to these valves from line **67** through a line **67***a*. The assembly **46** is used to control the right hand propel motor **26** and the assembly **48** is used to control the left hand propel motor **28**.

In accordance with the invention, hydraulic fluid for operating the cylinders **18**, **20** and **22**, the swing motor **24**, and the propel motors **26** and **28** is supplied by means of a number of double fixed volume fluid pump assemblies **50**, **52**, **54**, **56** and **62** which are driven off of the main engine **58** through the pump drive **60**. The double fixed volume pumps used herein are Vickers 4535 Vane pumps.

More particularly, each of the pump assemblies **50**, **52**, **54**, **56**, and **62** includes a high volume-low pressure pump **50H**, **52H**, **54H**, **56H** and **62H** and a low volume-high pressure pump **50L**, **52L**, **54L**, **56L**, and **62L**. The high volume-low pressure pumps are rated at 100 gallons per minute at a maximum pressure of 2500 p.s.i. and the low volume-high pressure pumps are rated at 60 gallons per minute at a maximum pressure of 3000 p.s.i. Each of the high volume pumps when operating at maximum capacity of 2500 p.s.i. require 150 horsepower. Each of the low volume pumps at maximum capacity of 3000 p.s.i. require 108 horsepower and when operating at the same pressure, 2500 p.s.i. as the high volume pump, require 90 horsepower. Whenever a high volume pump and a low volume pump are operating together at 2500 p.s.i. they will require 240 horsepower. It should, therefore, be apparent that four pump assemblies each requiring only 108 horsepower can operate simultaneously since the main engine has a maximum rating of 450 horsepower. Normally, all of the pump assemblies are not required to operate at any one time, however, if all of the pump assemblies were operating at maximum capacity, they would still exceed the horsepower available from the engine.

Means are provided for limiting the horsepower required from the engine **58** whenever the maximum capacity of the high volume pump in one of the pump assemblies is approached. Such means is in the form of a number of pilot operated bypass or unloading valves **55**, **66**, and **68** and a relief valve **69**. The unloading valves are connected to the pumps for the swing motor, boom and dipper stick, respectively. Each of the bypass valves when actuated will bypass fluid from the high volume-low pressure pumps to the reservoir. Relief valve **69** is operatively connected through a valve **110** to the pump for the dipper and propel motors to bypass the high volume to the reservoir. The operating pressure of the bypassed pump will immediately drop reducing the load on the engine.

More particularly, and referring specifically to the operation of the boom **12**, hydraulic fluid is supplied from the high volume-low pressure pump **50H** through line **70** to the reversing valve **30** and from the low volume-high pressure pump **52L** through the line **72**. The pilot operated unloading valve **66** is connected to the line **70** by a bypass line **74** and to the line **72** by a pilot line **76**. The unloading valve **66** is connected to the reservoir **78**

through a reservoir line **80**. (Whenever the reservoir **78** is designated on the drawing, it should be understood that a common reservoir is contemplated). Reverse flow of fluid through line **70** is prevented by means of a check valve **82** provided in the line **70** between the connections of the bypass line **74** and the low volume-high pressure line **72** to the line **70**. The valve **66** is set to open whenever the pressure in the line **70** reaches the maximum pressure capacity of pump **50H**, which is approximately 2500 p.s.i. This will occur whenever the boom engages an obstruction or lifts a heavy load and starts to stall. As the pressure builds up in lines **70** and **72** to overcome the obstruction, the unloading valve **66** will open to dump the fluid from pump **50H** to the reservoir **78** immediately reducing the operating pressure of pump **50H**. The pump **52L** will continue to supply low volume-high pressure fluid up to a maximum pressure of 3000 p.s.i. The load on the engine **58** is dropped from approximately 240 horsepower when operating both pumps at 2500 p.s.i. and limited to 108 horsepower when operating pump **50L** at 3000 p.s.i. When the pressure in line **72** drops below 2500 p.s.i., the valve **66** will close allowing high volume fluid from pump **50H** to flow to the boom cylinder.

The operation of the dipper stick **14** is substantially the same as the operation of the boom **12**. Fluid is supplied to the reversing valve **32** from the high volume-low pressure pump **52H** through line **84** and from the low volume-high pressure pump **50L** through line **86**. Unloading valve **68** is connected to line **84** through bypass line **88** and to line **86** through pilot line **90**. The valve **66** is connected to reservoir **78** through line **92**. Reverse flow of fluid through line **84** is prevented by means of a check valve **94** provided in line **84** between the connections of the line **88** and the line **86** to the line **84**. Whenever the pressure in line **86** approaches the maximum pressure of the hydraulic fluid from the pump **52H**, or approximately 2500 p.s.i., the valve **68** will be opened by the pressure of the fluid in line **90** bypassing hydraulic fluid from line **84** through line **88** to the reservoir **78**. The pump **50L** will increase the pressure of the fluid in line **86** to 3000 p.s.i., however, the pump **50L** only requires 108 horsepower to operate. When the pressure in line **86** drops below 2500 p.s.i., the valve **68** will close connecting pump **52H** to the reversing valve **32**.

The operation of the dipper **16** is also similar to the operation of the boom **12** and dipper stick **14**. Hydraulic fluid is supplied to the reversing valve **34** from high volume-low pressure pump **56H** through a valve **110B** in a double acting hydraulically actuated valve **110** by lines **96** and **96A** and from low volume-high pressure pump **54L** through lines **98**. The operation of the hydraulic valve **110** is more fully described hereinafter. The pilot operated relief valve **69** is connected directly to the line **98** through a pilot line **102** and to the valve **110** through a line **100** so that the valve **110** opens in response to a predetermined pressure of the fluid in line **98** as explained hereinafter. Fluid from line **96** is discharged through the valve **110B** to the reservoir **78** through line **122** whenever the relief valve **69** is opened. Reverse flow of fluid through lines **96** and **96***a* is prevented by means of a check valve **106** provided in the line **96***a*. The relief valve **69** and the valve **110** are set to open whenever the fluid pressure in the line **98** exceeds 2500 p.s.i. When the valve **110** is opened, the pressure of the fluid in line **98** will build up to a maximum pressure of 3000 p.s.i. or until the dipper has cleared the obstruction drawing a maximum of 108 horsepower from the engine **58**. When the pressure in line **98** drops back to 2500 p.s.i., the pump **56H** will be connected to reversing valve **34**.

The swing motor **24** is operated substantially in the same manner as the cylinder for the boom and dipper stick. Fluid is supplied to the reversing valve **36** from the high volume-low pressure pump **62H** through line **37***a* and from the low volume-high pressure pump **62L**

through line 37*b*. Unloading valve 55 is connected to line 37*b* by pilot line 57 and to line 37*a* by bypass line 59. The valve 55 is connected to reservoir 78 by line 53. Reverse flow of fluid through line 37*a* is prevented by check valve 51 provided in line 37*a* downstream from bypass line 59. Whenever the pressure in line 37*b* exceeds 2500 p.s.i., the valve 55 will be opened bypassing fluid from line 37*a* to the reservoir 78 and reducing the load on the engine 58. When the pressure drops below 2500 p.s.i., the valve will again close connecting the pump 62H to reversing valve 36.

From the above, it should be apparent that the boom, dipper stick, dipper and swing motor can be operated simultaneously under stall conditions without overloading the engine 58. When operating at maximum pressure of 3000 p.s.i., the pumps 50L, 52L, 54L and 62L will each only be using 108 horsepower. They will only be using 432 horsepower at maximum stall condition.

Means are provided for simultaneously shifting both propel motors 26 and 28 to the low volume-high pressure pumps 54L and 56L whenever either of the propel motors requires maximum pressure to operate. Such means is in the form of the double acting hydraulically actuated valve 110 which is connected to respond to the same pressure as the pilot operated relief valve 69 through the line 100 to either connect the pumps 54H and 56H to the propel motors or to the reservoir 78.

More particularly, hydraulic fluid is supplied to the reversing valve 42 for the right hand propel motor 26 from the low volume pump 54L through line 98, reversing valve 34 and line 112 and from the high volume pump 56H through line 96, valve 110B and line 96*a*. These are the same pumps which are used to operate the dipper, however, it is generally understood that the dipper is not used whenever the propel motors are operating, therefore, the same pumps can be used for both purposes. Hydraulic fluid is supplied to the reversing valve 44 for the left hand propel motor 28 from the high volume pump 54H through a line 114, valve 110A and line 114*a* and from the low volume pump 56L through a line 116. Reverse flow of fluid through line 114*a* is prevented by means of a check valve 113 provided in the line 114*a*. The low volume-high pressure line 116 is connected to the relief valve 69 through pilot line 111. Check valves 120 are provided in the pilot lines 111 and 102 to prevent the flow of high pressure fluid from line 116 to line 98 or line 98 to line 116. The relief valve 69 will open whenever the pressure in either of the lines 98 and 116 exceeds 2500 p.s.i.

The hydraulically actuated valve 110 is connected to respond to the pressure in pilot lines 102 and 111 by the line 100 through valve 69. The valve 110 is normally biased by a spring 109 to close the valves 110*a* and 110*b* to direct the fluid from lines 96 and 114 directly to the reversing valves 42 and 44 through lines 96*a* and 114*a*. Whenever the pressure in either of the pilot lines 102 or 111 reaches 2500 p.s.i., valve 69 will open. The pressure in line 100 will also increase sufficiently to open valve 110 and connect both lines 96 and 114 to the reservoir 78 through line 122. Both propel motors 26 and 28 will then be operated by the low volume pumps 54L and 56L. This system for providing simultaneous shifting of the two hydraulic motors 26 and 28 to low pressure or high pressure operation can also be used to simultaneously shift any two of the boom, dipper stick or dipper cylinders between low pressure and high pressure operation.

Means are provided for cooling a portion of the hydraulic fluid circulating through the system prior to return to the reservoir 78. Such means includes the oil cooler 130 mounted on the engine 58 connected to the reservoir 78 by a line 132. The return line 29 from the reversing valve 44 is connected directly to the oil cooler 130. The return line 122 from valve 110 is also connected to the line 29 for return of fluid through the oil cooler 130. A bypass line 134 is provided between lines 29 and line 132 and includes a relief valve 136 which is set to open at 100 p.s.i.

Although the invention has been described as using two fixed volume pumps for each hydraulic cylinder or motor, more than two can be used is desired. This is of particular significance where a more gradual change in load on the engine is required. Each additional fixed volume pump can be unloaded or bypassed at different line pressures.

RÉSUMÉ

By means of the present invention the horsepower required to operate the various functions of hydraulically operated lifting or digging equipment such as truck cranes, back hoes, diggers, front end loaders and winches at any one time can be limited to thereby reduce the horsepower required for the main engine. This is achieved by using a number of low cost pump assemblies each having two fixed volume pumps to provide hydraulic fluid to operate the equipment. Pilot operated unloading valves are connected to the pumps to respond to a predetermined operating pressure to bypass one of the pumps to the reservoir and reduce the operating pressure of the bypassed pump. In this particular system, a separate pair of pumps can be chosen to provide the required performance for any function.

A novel hydraulic control is also provided to simultaneously shift the pumps for any two operating functions from low pressure to high pressure or high pressure to low pressure to maintain the same hydraulic force for the two operating functions.

What is claimed is:

1. A hydraulic power transmission system for hydraulically operated digging equipment having a boom, a stick, a dipper, an engine having a common pump drive, a double acting hydraulic cylinder for each of the boom, stick and dipper and for controlling the operation thereof, said system including.

a number of double fixed volume pump assemblies connected to the common pump drive, each assembly including a low volume high pressure pump and a high volume low pressure pump,

each of said cylinders for said boom, stick and dipper being connected to a low volume high pressure pump in one of said pump assemblies and to a high volume low pressure pump in another of said pump assemblies,

and a pilot operated bypass valve connected to respond to the pressure of said low volume high pressure pump in each assembly for bypassing the cross connected high volume low pressure pump for the corresponding cylinder.

2. A hydraulic power transmission system for hydraullically operated digging equipment having a boom, stick and a dipper, a double acting hydraulic cylinder connected to operate each of said boom, stick and dipper, a pair of hydraulic propel motors, a swing motor and a main engine having a horsepower rating less than required to simultaneously operate all of the cylinders and motors at maximum capacity, said system comprising,

a number of hydraulic pump assemblies operatively connected to the main engine.

each of said pump assemblies including a high volume-low pressure pump and a low volume-high pressure pump,

one of said high volume-low pressure pumps in each assembly and one of the low volume-high pressure pumps in another of the assemblies being connected to each of the cylinders and motors,

and means responsive to the fluid pressure of the low volume-high pressure pumps for bypassing fluid from the high volume-low pressure pump for the corresponding cylinder.

3. The hydraulic power transmission system of claim 2 wherein said bypassing means comprises a pilot operated unloading valve operatively connected to respond to the low volume-high pressure pump for each cylinder and motor to bypass the high volume-low pressure pump for the corresponding cylinder.

4. The hydraulic power transmission system according to claim 2 including a double acting hydraulic selector valve connected to the high volume-low pressure pumps for the propel motors and

said bypassing means for said propel motors being connected to actuate said valve to simultaneously shift both propel motors to low volume-high pressure operation when the pressure at either of said propel motors exceeds a preset pressure.

5. A hydraulic power transmission system for hydraulically operated digging equipment of the type having an engine, a boom, a stick, a dipper and a pair of propel motors,

a number of double-fixed volume pump assemblies operatively connected to the engine,

each assembly having a high volume-low pressure pump and a low volume-high pressure pump.

one high volume-low pressure pump in said pump assemblies being connected to each of said propel motors,

said low volume-high pressure pump in the corresponding pump assembly being cross connected to the other of said propel motors, and

means responsive to a predetermined pressure in either of said high pressure pumps to simultaneously bypass both of said low pressure pumps.

6. The system according to claim 5 including a double acting hydraulic cylinder for controlling each of said boom, stick and dipper,

one of said fixed volume low pressure pumps being connected to each of said cylinders,

one of said fixed volume high pressure pumps from another of said assemblies being connected to each of said cylinders, and

means responsive to a predetermined pressure in said high pressure pumps to bypass the fluid of the low pressure pumps.

7. A hydraulic power transmission system for hydraulically operated digging equipment having a boom, a stick,

a dipper and an engine, a double acting hydraulic cylinder for each of the boom, stick and dipper and for controlling the operation thereof, said system including

a number of double fixed volume pump assemblies operatively connected to the engine, each assembly including a low volume-high pressure pump and a high volume-low pressure pump.

each of said cylinders for said boom, stick and dipper being connected to a low volume-high pressure pump in one of said pump assemblies and to a high volume-low pressure pump in another of said pump assemblies,

means responsive to the pressure of said low volume-high pressure pump in each assembly for bypassing the cross connected high volume-low pressure pump for the corresponding cylinder, and

a pair of hydraulic propel motors,

one of said low pressure-high volume pumps in one pump assembly and one of said high volume-low pressure pumps in another pump assembly being connected to provide hydraulic fluid to each of the propel motors and

means responsive to the pressure of the low volume-high pressure pump connected to each of said propel motors for simultaneously bypassing the high pressure low-volume pump connected to each of the propel motors.

8. A hydraulic power transmission system according to claim 7 wherein said bypassing means includes a double acting hydraulic valve connected to the high volume-low pressure pump for each propel motor.

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U.S. Cl. X.R.

214—762; 60—52HE; 417—62